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Where emotion meets cognition

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Functional impairments of OCD patients on a visuomotor associative learning task

Abstract

Patients with Obsessive-Compulsive Disorder (OCD) frequently have to repeat their actions before feeling certain that these were performed correctly, which may be due to a failure in processing the emotional significance of response feedback. We examined performance of OCD patients ($n = 29$) and healthy volunteers ($n = 28$) on a visuomotor discriminative learning task, in which feedback valence was manipulated with monetary gains and

losses. As predicted, OCD patients were profoundly impaired in the acquisition of visuomotor associations. Further, the emotional salience of feedback mediated only performance of OCD checkers. Our data suggest that OCD patients have a fundamental impairment in processing the outcome of their actions, and that the influence of emotions on these processes vary with the subtype of OCD.

Introduction

ONE STRIKING FEATURE of Obsessive-Compulsive disorder (OCD) is the repetitive nature of the compulsive actions that are performed by people suffering from the disorder. Patients report that they cannot feel safe until they have performed the compulsive acts for many times and according to strict routines. It seems as if OCD patients somehow cannot use the feedback they receive whilst carrying out their actions. Indeed, it has been proposed that OCD symptoms are due to failures in processing performance feedback (Otto, 1992). Such a failure might compromise the ability to determine the behavioural relevance of an action, thereby leading to doubt and the urge to repeat actions.

Interestingly, neuroimaging studies in OCD lend credibility to the feedback hypothesis. One of the most consistent findings in the OCD literature is increased resting activation of the ventromedial prefrontal cortex (vmPFC) (Baxter et al., 1992; Perani et al., 1995; Swedo et al., 1989). In healthy volunteers, activity of the vmPFC is specifically enhanced when performing guessing tasks (Elliott et al., 1999; O'Doherty et al., 2001; Rogers et al., 1999). A characteristic feature of guessing tasks is that subjects cannot use a rational strategy to decide what course of action to take. As a result, subjects can only make a choice for a particular stimulus after contemplating on previous successes and failures, thereby making behaviour strongly dependent on the emotional meaning of feedback. The feelings of hope and disappointment that accompany positive and negative feedback are according to some theories crucial for successful choice behaviour (Damasio, 1994). They also play a part in recent cognitive accounts of judgment and decision making (Mellers et al., 1998). The importance of the vmPFC for adequate social and moral behaviour has been illustrated by clinical neuropsychology. Patients with acquired lesions of the vmPFC are very severely impaired in making personal choices, while their cognitive and intellectual abilities are preserved (Rolls et al., 1994; Bechara et al., 1994; Bechara et al., 2000). Therefore, the abnormal activity of the vmPFC in OCD suggests that it is particularly the processing of the affective significance of feedback that is altered in this disorder.

Following this line of reasoning, recent studies examined whether OCD patients can use the feelings that are induced by positive and negative reinforcement to adapt in a complex decision-making task. This task, originally developed by Bechara and colleagues (Bechara et al., 1994), consists of a long series of card selections from four different decks. Unknown to the subject, each deck is associated with a different reward-schedule (connotated as either 'risky' or 'safe'). Subjects can use the monetary reinforcement that is provided after each response

to develop a bias towards the safe decks (Damasio, 1994). OCD patients who were tested with this paradigm displayed a remarkable diversity in their behaviour. Cavedini and colleagues (2002) found that those OCD patients who did not respond to later pharmacological treatment persisted in making choices from risky decks. In contrast, OCD responders displayed normal decision making. In another study, it was a subset of severely symptomatic patients that adapted significantly worse than moderately ill patients, whereas the OCD group as a whole performed normally (Nielen et al., 2002).

The lack of consistent decision-making behaviour in OCD makes it difficult to infer whether the deficit in feedback processing is genuine or not. Therefore, in the current study, we decided to study feedback processing in OCD with another paradigm. This task is a visuomotor associative learning task, which requires subjects to learn different stimulus-response combinations on a trial-and-error basis. Successful performance depends on the ability to relate the success of a particular response with the stimulus (Passingham et al., 2000). If OCD patients fail to encode the outcome of a response, they will be slower in acquisition of the stimulus-response associations. Furthermore, if the emotional salience of feedback is a crucial factor in mediating OCD symptoms, it might be worthwhile to see whether it modulates their learning behaviour as well. To examine this,

Table 1 — Distribution of monetary gains and losses for the *Reward*- and *Cost*-condition of the visuomotor associative learning task.

	Reward	Cost
hit	+10	0
error	0	-10

we manipulated the affective content of the feedback message by introducing monetary rewards and penalties. Positive affect was induced in the *reward*-condition. Here, subjects won money with a correct response and received no penalty for an error. In contrast, in the *cost*-condition, negative affect was elicited by punishing the occurrence of an error while correct responses were followed by non-reward (see table 1).

Patients with anxiety disorders are believed to be more sensitive to signals of punishment and non-reward than healthy subjects (Fowles, 1988; Gray, 1982). Indeed, OCD patients tend to become markedly more anxious in situations when they feel personally responsible to prevent a dreaded event from happening (Salkovskis et al., 1999). Therefore, we predicted that associative learning of OCD patients is more easily disrupted by aversive stimulation than by reward. We also explored whether this phenomenon was general for OCD or limited itself to a particular subgroup of patients (i.e. ‘washers’ or ‘checkers’).

Increased sensitivity to costs may impair the encoding of associations, resulting in an overall lowered level of accuracy. In addition, punishment may have its effect on the response to the next trial. For instance, patients may be confused by the punishment and therefore fail the following problems. This would be rather similar to the ‘catastrophic response to perceived failure’ that has been observed in depressive patients (Beats et al., 1996; Elliott et al., 1997; Steffens et al., 2001). Finally, losing money may make OCD patients extremely cautious, resulting in a slowing down of motor speed.

To summarize, this study was set up to examine whether OCD patients are impaired in using feedback for visuomotor associative learning. We expected that such an impairment would reveal itself as a slower improvement of learning in OCD patients as compared to controls. In addition, OCD patients would be more sensitive to aversive stimulation. This could lower accuracy scores in the *cost*-condition, and have an effect on either response patterns or motor speed.

Method

Participants

The study was approved by the local ethics committee of the University Hospital Groningen. Twenty-nine patients who met the DSM-IV (APA, 1994) criteria for Obsessive-Compulsive Disorder agreed to participate in the study. The presence of OCD was confirmed in a diagnostic interview by an experienced clinician. None of the patients had comorbid medical or neurological illness. One OCD patient displayed motor tics. Severity of obsessive and compulsive symptoms was assessed with the Yale Brown Obsessive-Compulsive Scale (Y-BOCS) (Goodman et al., 1994). In addition, the symptom checklist of the Y-BOCS was used to identify the nature of the obsessive and compulsive symptoms. All OCD patients that were included in the study suffered from both obsessive and compulsive symptoms. Severity of comorbid depressive symptoms was assessed with the 17-item Hamilton Depression Rating Scale (HDRS) (Hamilton, 1960). Seventeen OCD patients were taking psychotropic medication at the time of the study. Eleven of these patients were using selective serotonergic reuptake inhibitors (SSRIs), five were taking the tricyclic antidepressant clomipramine, and one used a beta-blocker only. One OCD patient combined SSRI medication with benzodiazepines. Within the OCD group, five patients did not complete the IQ-test. However, the mean educational level of these patients did not differ from that of the other patients.

Healthy adults ($n = 28$) were recruited from outside the hospital with the aid of advertisements and paid for their participation. They were matched to the patient group with respect to age, sex, and estimated IQ. None of the healthy control subjects reported a history of psychiatric or neurological illness. All subjects provided written informed consent after the study procedure had been explained to them.

Experimental task

We used a two-choice associative learning task that was adapted from Iaboni and colleagues (Iaboni et al., 1995). This task required subjects to learn an association between a particular stimulus and a go-nogo response (i.e. pressing the space bar or not). Stimuli consisted of ten two-digit numbers, randomly drawn from the range between 10 and 90. They were presented for 2000 ms on a black computer screen. Within the stimulus presentation time, subjects were required to press the space bar or leave it. If the subject had not responded within 1500 ms, feedback on response accuracy was provided on the screen. In case of a correct response, a positive feedback text ('YOU WIN!') was displayed on the screen. In case of an error, negative feedback ('YOU LOSE!') was provided. In both cases, the monetary gain of the response (either +10, 0 or -10 cents) and the total amount of money that had been gained hitherto accompanied the feedback message. The task consisted of 5 consecutive blocks, each consisting of 50 trials. Between every block there was a short pause of 30 seconds. The same set of digits was used throughout the whole task but different sets of randomly drawn digits were used for the two conditions. Order of condition ('reward' or 'cost') and stimulus sets were counterbalanced between subjects. Feedback valence was manipulated as follows. In the *reward*-condition, for every correct response 10 cents were added to the starting amount (0 cents). Subjects lost 0 cents for an incorrect response. In the *cost*-condition, subjects started with 200 cents, lost 10 cents for every incorrect response and won 0 cent for a correct response (see table 1). The presentation of the stimuli and timing of various events was controlled by the Micro Experimental Laboratory (MEL) software (version 2.01, Psychology Software Tools Inc., Pittsburgh USA). Accuracy and latency of responses was collected automatically with this software.

Procedure

Subjects were tested in the laboratories of the Department of Psychology, University of Groningen and of the Department of Psychiatry, University Hospital Groningen. Subjects came to the laboratory for a morning or afternoon testing session. Before the experiment started, participants completed the shortened version of the Raven Progressive Matrices (part B, C and D) which provides an estimate of 'fluid', nonverbal intelligence. After explanation of the procedure of the visuomotor associative learning task, a short practice session (30 trials) was given in order to get subjects used to the task. Monetary incentives were not introduced until the start of the actual experiment. Subjects were told that they could keep the total amount of money that they gained in both tasks, so they were emphasized to do their best. After completion of the tasks, all subjects received the same net amount of money (f 25,- = € 11.36) for participating in the experiment. In all cases, this exceeded the total amount of money that the subject had actually won in both conditions. The length of the total testing session was 2 hours, including a 15-minute break halfway through the session.

Data Analyses

Analysis of variance

Data were analyzed using SPSS version 9.0 (SPSS Inc; Nie et al., 1986). Demographic and clinical characteristics of OCD patients and healthy controls were compared with one-way analysis of variance (ANOVA). Comparison of gender was made using the chi-square test. A repeated measures ANOVA with Condition (2 levels) and Block (5 levels) was used to compare accuracy and latency on the associative learning task. Repeated measures of analysis (ANOVA) with Condition (2) and Group (2) was used to test for main and interaction effects on conditional probability and Z-scores of the runs test (see below). Post-hoc paired or unpaired t-tests (two-tailed) were used to examine the nature of potential interaction effects.

Conditional probability and the runs test

As noted before, we used two different methods to test whether OCD patients were more sensitive to costs. First, we computed the conditional probability (CP) of a subject failing a trial, given that they had failed the trial directly preceding it. The CP is derived by dividing the total number of subsequent errors by the total number of errors made (Shah et al., 1999). This method assumes that since the

number of subsequent errors is divided by the total number of errors, the difference in overall failure rate is controlled for (Elliott et al., 1997). In other words, a subject who makes twice as many errors as another subject, is expected to make twice as many subsequent errors. Therefore, the CP for both subjects would be equal. Second, we used the nonparametric runs test (Siegel & Castellan, 1988) to examine whether the distribution of errors for each condition was comparable for the two groups. This was done because there is evidence that CP analysis is influenced by the total number of errors made. In contrast, the runs test makes a prediction of the number of ‘runs’ that would be expected based on the number of correct responses and errors. A ‘run’ is defined as a succession of one or more identical events, followed and preceded by the alternative event (Siegel & Castellan, 1988). For example, the following series of 12 binary responses [00-11-0-1111-00-1] consists of 6 runs. The runs test calculates the chance probability of having a particular number of runs in a series, given the number of hits and errors that were made in the series. The difference between the number of runs that is actually *observed* and the number of runs that was *predicted* can be expressed in a Z-score. Mean Z-scores < -1.96 indicate that there is statistically significant grouping of errors (i.e. fewer runs), whereas mean Z-scores > 1.96 demonstrate that there are more runs than expected by chance only. In both cases the null hypothesis (which states that the distribution of errors is random) is rejected. If our hypothesis is correct, then OCD patients will make more consecutive errors in the *cost*-condition than in the *reward*-condition. This means that they will produce fewer runs than expected in the *cost*-condition compared to the *reward*-condition. In other words, the Z-cost will be significantly more negative than the Z-reward.

Correlations between symptoms and task performance

Pearson product moment correlation coefficients were computed to estimate correlations between clinical characteristics of OCD patients and task performance.

Results

Demographic and Clinical Characteristics

OCD patients ($n = 29$) did not differ from normal controls (NC, $n = 28$) with respect to age (OCD: 34.4 ± 10.4 vs. NC 31.5 ± 11.3 , $p = 0.315$), estimated IQ (OCD: 111.9 ± 7.2 vs. NC: 113.5 ± 11.3 , $p = 0.557$) and gender (OCD: 20 women vs. NC: 20 women,

$p = 0.839$). Mean total Y-BOCS score for OCD patients was 20.4 ± 5.03 , with a mean score of 9.79 ± 2.96 for the Obsession subscale and 10.62 ± 3.22 for the Compulsion subscale. OCD patients had significantly higher levels of depression (OCD: 7.92 ± 4.5 vs. NC: 1.04 ± 1.4) and anxiety (OCD 12.9 ± 6.6 vs. NC 1.5 ± 3.4) than controls. Six OCD patients presented with predominantly washing symptoms, the other 23 patients were categorized as having mainly symptoms of checking. There were no demographic or clinical differences between unmedicated OCD patients and medicated OCD patients.

Accuracy of Performance

OCD patients versus normal controls

Due to a failure in the computer program, data of 12 healthy subjects was missing for the 5th block of the *reward*-condition. In order to avoid losing data on the *cost*-condition, the missing data were substituted by the mean accuracy rates of the remaining control subjects. Despite the fact that order of condition was counterbalanced within groups, we examined potential confounding effects of task order on performance using a group (2) \times condition (2) \times task order (2) ANOVA on accuracy. Main effects failed to reach significance, although there was a significant Condition \times Task order interaction ($F_{1,53} = 7.57$, $p = 0.008$). Overall, subjects performed consistently better in the second condition than in the first, which might be due to increased familiarity with the task procedure.

Correct responses consisting of hits (i.e. pressing for active stimuli) and correct rejections (not pressing for active stimuli) were computed for each of the five blocks of the two conditions. Exploratory analyses revealed that one healthy control had extremely low accuracy scores on the *reward*-condition due to consistent non-pressing of the space bar. Since this subject also had slightly elevated scores on the HDRS and HARS (8 and 6 respectively) we analyzed the data with and without this subject. Since this did not affect the significance of the results we decided to remove this subject from the analyses.

Using a repeated measures of analysis of variance with Condition (2) and Block (5) as within-variables and Group (2) as between-variable, we found a significant main effect of Block ($F_{4,52} = 131.10$, $p < 0.001$) demonstrating that both groups improved their performance as the task progressed. More importantly, there was a main effect of Group ($F_{1,55} = 10.54$, $p = 0.002$) revealing that for both conditions, accuracy scores of OCD patients were significantly lowered. There was also a Block \times Group interaction ($F_{4,52} = 2.70$, $p = 0.040$) suggesting that OCD patients learned at a different speed than controls.

We then used repeated measures of analysis with a 2 (Condition) \times 2 (Block) \times 2 (Group) design in order to find out in what stage of the task these differences occurred. This analysis produced a significant Block \times Group interaction, only for the second stage (i.e. between block 2–3) of the task ($F_{1,55} = 9.71$, $p = 0.003$). Here, OCD patients showed a significant improvement of their performance ($t_{55} = -3.12$, $p = 0.003$), while normal controls already displayed a ceiling effect in their performance (see figure 1a).

The omnibus ANOVA did not yield a main effect of Condition ($F_{1,55} = 2.38$, $p = 0.128$). We did not find a Group \times Condition interaction or the Group \times Condition \times Block interaction either.

Only within normal controls, there was a significant Condition \times Block interaction for the final stage of the task ($F_{1,27} = 5.03$, $p = 0.033$). Paired t-tests showed that controls continued to improve performance in the *cost*-condition ($t_{27} = -3.38$, $p = 0.002$) but not in the *reward*-condition ($t_{27} = -0.662$, $p = 0.514$). Within the OCD group, there were no significant main or interaction effects.

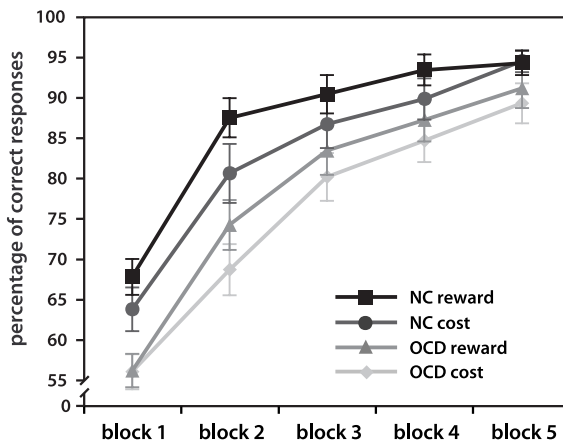


Figure 1a — Accuracy performance (expressed as percentage correct) in the reward and the cost-condition for the whole OCD sample ($n = 29$) and healthy volunteers ($n = 28$). Bars represent standard errors of the mean (S.E.M.).

OCD checkers vs normal controls

The proportion of OCD checkers that started with the *cost*-condition or the *reward*-condition did not differ from that in controls (controls: 14 Cost vs 14 Reward; OCD checkers: 13 Cost vs 10 Reward, $\chi^2 = 0.22$, $p = 0.64$). Omnibus ANOVA with Block (5) and Condition (2) as within-subject variables and Group

(2) as between-subject variable revealed a significant main effect of Group ($F_{1,49} = 7.61$, $p = 0.008$) and Block ($F_{1,49} = 129.86$, $p < 0.001$). In addition, there was a significant interaction between Block and Group ($F_{1,49} = 2.83$, $p = 0.035$). As was previously found for the entire OCD sample, this effect was due to the significant improvement of OCD checkers in the second stage of the task ($t_{49} = 2.99$, $p = 0.004$), in contrast to normal controls.

This time the omnibus ANOVA also yielded a significant main effect of Condition ($F_{1,49} = 5.8$, $p = 0.020$). Overall, subjects performed better in the *reward*-condition than in the *cost*-condition (paired t-tests: $t_{50} = -2.27$, $p = 0.027$). There were no significant Condition \times Group or Condition \times Group \times Block interactions. Separate between-group comparisons for each consecutive pair of blocks demonstrated a significant interaction between Block \times Condition for stage 1 ($F_{1,49} = 5.95$, $p = 0.018$) and stage 2 ($F_{1,49} = 5.52$, $p = 0.023$). Subjects learned better under reward than under costs (paired t-tests; stage 1: $t_{50} = -2.33$, $p = 0.024$ and stage 2: $t_{50} = 2.37$, $p = 0.022$). Again, the Group \times Condition \times Block interaction and the Condition \times Group interaction were not significant. Within-group analysis of performance of OCD checkers yielded a significant Condition \times Block interaction in the first stage of the task ($F_{1,22} = 6.6$, $p = 0.017$). Within this stage, OCD checkers improved their performance significantly more under reward than under costs (paired t-test: $t_{22} = -2.58$, $p = 0.017$) (see figure 1b).

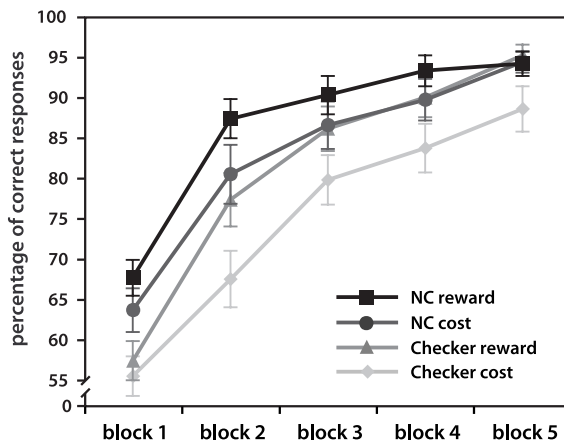


Figure 1b — Accuracy performance (expressed as percentage correct) in the reward and the cost-condition for OCD with checking symptoms ($n = 23$) and healthy volunteers ($n = 28$). Bars represent standard errors of the mean (S.E.M.).

Reaction Times

OCD versus normal controls

We analyzed latencies of all go-responses (thus comprising both hits and false alarms). Analysis of variance with Group (2) as between-factor and Block (5) and Condition (2) as within-subject variables, revealed a significant main effect of Block ($F_{4,52} = 17.16$, $p < 0.001$), demonstrating that both groups displayed a practice-related speeding of responses over time (see figure 2a). In addition, there was a main effect of Group ($F_{1,52} = 10.96$, $p = 0.002$) revealing that OCD patients overall needed more time to respond to the stimuli. There was no significant main effect of Condition. This analysis did not reveal any significant interaction effects. Finally, we compared mean latency of responses that were made immediately after an error. Increased latencies could be a manifestation of the effect of costs on decision times. However, we did not find significant main or interaction effects.

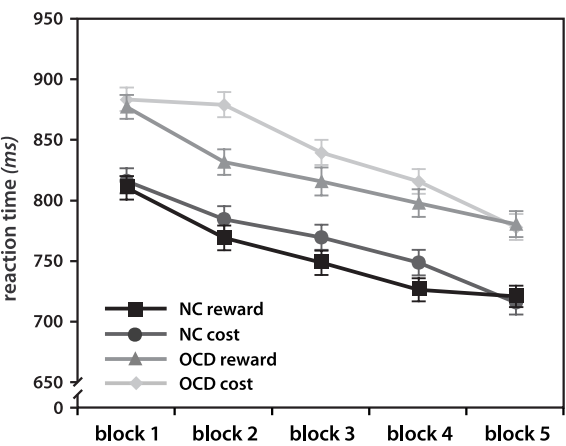


Figure 2a — Mean response latency for go-responses (hits + false alarms) for OCD patients ($n = 29$) and healthy volunteers ($n = 28$). Bars represent standard errors of the mean (S.E.M.).

OCD checkers versus normal controls

The omnibus ANOVA on all go-responses revealed significant main effects of Group ($F_{1,49} = 9.08$, $p = 0.004$) and Block ($F_{4,46} = 17.42$, $p < 0.001$). There was trend-like evidence for a significant main effect of Condition ($F_{1,49} = 3.88$, $p = 0.054$). When we compared reaction times in consecutive pairs of blocks, the

main effect of Condition was significant for the first and second stage of the task (block 1: $F_{1,49} = 5.76$, $p = 0.020$; block 2: $F_{1,49} = 7.46$, $p = 0.009$). Furthermore, the omnibus ANOVA yielded a significant Condition \times Block interaction ($F_{4,46} = 2.64$, $p = 0.046$); other interactions were not significant. Within-group analysis in OCD checkers revealed a Condition \times Block interaction in stage 1 ($F_{1,22} = 7.74$, $p = 0.011$). Post-hoc paired t -tests showed that OCD checkers displayed a significant improvement of reaction times under reward ($t_{22} = 3.58$, $p = 0.002$) while those under costs did not drop until the second stage of the task ($t_{22} = -0.159$, $p = 0.875$) (see figure 2b). Finally, OCD checkers needed in general more time to respond after an error than normal controls ($F_{1,49} = 4.30$, $p = 0.043$) although this was not modulated by Condition.

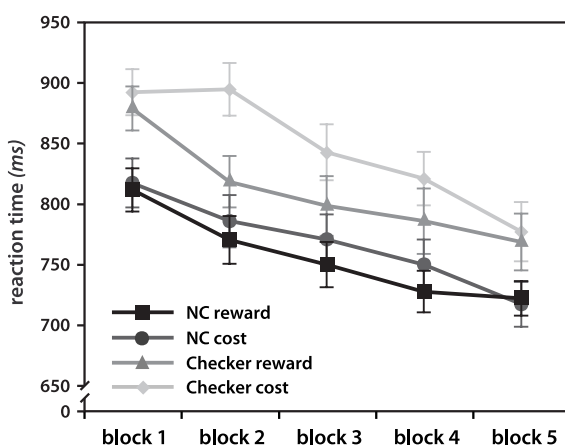


Figure 2b — Mean response latency for go-responses (hits + false alarms) for OCD checkers ($n = 23$) and healthy volunteers ($n = 28$). Bars represent standard errors of the mean (S.E.M.).

Conditional probability and the runs test

We computed the mean conditional probability of making an error for both OCD patients and controls (results are depicted in figure 3). There was a main effect of Condition ($F_{1,55} = 9.26$, $p = 0.004$) indicating that both groups were more likely to make consecutive errors in the reward-condition compared to the *cost*-condition. There was also a main effect of Group ($F_{1,55} = 8.93$, $p = 0.004$) demonstrating that OCD patients were more likely than normal controls to make an error again once a trial was failed. The Condition \times Group interaction was

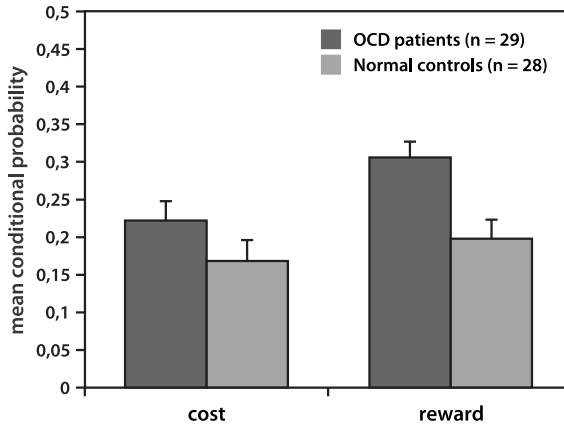


Figure 3a — Mean conditional probability from the runs test for feedback learning under conditions of reward and punishment in oCD patients (n = 29) and healthy volunteers (n = 28). Bars represent standard errors of the mean (S.E.M.).

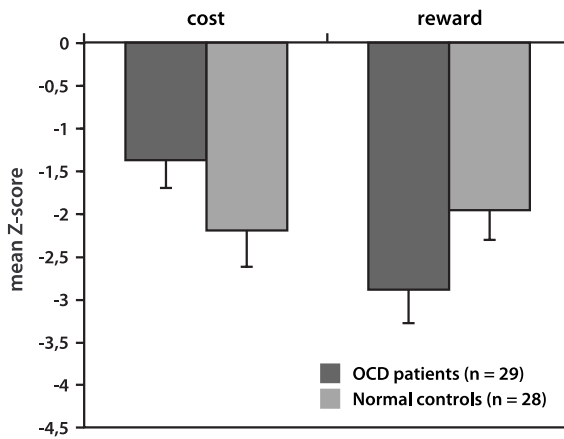


Figure 3b — Z-scores from the runs test for feedback learning under conditions of reward and punishment in oCD patients (n = 29) and healthy volunteers (n = 28). Bars represent standard errors of the mean (S.E.M.).

not significant, indicating that the emotional meaning of feedback did not affect this behavioural tendency. When we plotted total number of errors against the number of consecutive errors for each condition, we found a curvilinear relationship between the two parameters (data not shown here). These findings confirm earlier results by Shah and colleagues (1999) and suggest that both parameters

are not independent of each other. Therefore, the use of the runs test seems justified. We used analysis of variance with Condition (2) and Group (2) to test whether Z-scores on the runs test differed between the groups. This analysis did not yield a significant main effect of Group, indicating that the error distribution of OCD patients was equal to the one of normal controls ($F_{1,55} = 0.021$, $p = 0.89$). However, we found a clearly significant Group \times Condition interaction ($F_{1,55} = 7.42$, $p = 0.009$). This was due to OCD patients producing significantly fewer runs in the reward-condition as compared to the *cost*-condition ($t_{28} = 3.46$, $p = 0.002$). In contrast, the number of runs produced by normal controls was not modulated by condition ($t_{27} = -0.50$, $p = 0.62$). Finally, comparison of CP and the number of runs between OCD checkers and normal controls did not reveal significant differences between the two groups.

Correlations between symptomatology and task performance

Within the OCD group, severity of comorbid depressive and anxiety symptoms was highly associated ($r = 0.699$, $p = 0.002$). Severity of depressive symptoms was also related to severity of obsessions ($r = 0.405$, $p = 0.026$). We did not find significant correlations between task performance and either clinical or demographic characteristics of OCD patients.

Discussion

The primary aim of this study was to find evidence for impairments in processing of response feedback in OCD. This was investigated with a visuomotor associative learning task in which different stimulus-response combinations were learned on a trial-and-error basis. Positive and negative emotions, induced by either monetary rewards or penalties, were expected to affect the encoding of stimulus-response associations differently.

The results reveal that OCD patients generally recalled fewer stimulus-response associations than controls. In addition, their increased response latencies suggest that they also needed more time to decide upon the response that was to be given to a particular stimulus. Together, these findings refer to a profound deficit in the ability to learn visuomotor associations. Contrary to our initial hypothesis, we did *not* find evidence that the OCD group as a whole learned poorer under conditions of cost than under conditions of reward. However, learning of OCD

patients with checking symptoms seemed to be specifically disrupted by the presence of costs. These results are discussed in the remainder of this section.

Accuracy data of the OCD patients reveal that it was already after the first block of trials that OCD performance clearly fell behind that of controls. Throughout the task, their learning curves remained consistently lowered, and it was only with extended practice that OCD patients arrived at a normal level of performance. These data point to an obvious delay in associative learning, which seems to be due to a disability in rapid visuomotor learning early on in the task. It is specifically in this first stage that performance is very much reliant on feedback information, and therefore we think that our results support the main hypothesis that OCD patients have a fundamental deficit in processing the outcome of their actions.

Furthermore, the presence of a feedback processing deficit may also have consequences for the personal experience of memory. In the initial stage of the task, subjects have to rely on a trial-and-error strategy to find out what response should be given to a specific stimulus. This means that as the task starts, their choice behaviour is merely driven by random guesses. However, as the task progresses, and some visuomotor associations become selectively reinforced while others are not, implicit memory will gradually come into play. These memory processes may not provide all the information that is needed for conscious recollection of the correct response, but yet it may be just enough to produce a subjective 'feeling' that a certain response is better than the other. Similar feelings have been documented in the field of memory research (e.g. 'feeling of knowing') and they relate to a different phenomenal experience of memory than conscious recollection does (Tulving, 1985; Knowlton & Squire, 1995). Although tentative, it is possible that the feedback impairment not only interferes with objective memory performance, but also hinders the development of subjective preferences that accompany early learning. It would be interesting to see whether this impairment also accounts for the feelings of doubt and insecurity that are so typical for OCD.

The second important finding of this study is that emotional experiences, induced by the valence of feedback, did *not* affect associative learning of the OCD patient group. That is, the presence of punishment did not have a deteriorating effect on accuracy performance of OCD patients. Condition probability analysis revealed that OCD patients were also not more likely to fail a subsequent trial in the *cost*-condition compared to the *reward*-condition. Although this method suggested that OCD patients were *in general* more sensitive to negative feedback (thus, regardless whether it was followed by a penalty or not), this finding might

have been an artefact of the increased number of total errors made by the OCD group. This was supported by the runs test, which revealed that OCD patients had a normal level of clustering in their responses. Results from the runs test also demonstrated that the presence of costs resulted in *more* runs than the presence of reward, suggesting that penalties motivated OCD patients to do their best. In other words, our data do not support the hypothesis that OCD patients are generally more sensitive to the presence of aversive outcomes.

We did find, however, an effect of feedback valence on accuracy performance of a particular subgroup of OCD patients, namely those with checking symptoms. These checkers had significantly more problems with the acquisition of the stimulus-response associations when the loss of money was at stake. This finding was substantiated by the slowed responding of OCD checkers in the second block of the *cost*-condition, while there was a normal practice-related speeding of motor behaviour in the reward-condition. The increased sensitivity of OCD checkers to costs did not make them more likely to fail subsequent trials in the *cost*-condition, though. Together, these findings seem to imply that the emotional salience of feedback plays a crucial role in compulsive checking behaviour. More specifically, the negative emotions that are induced by the threat of an aversive outcome, seem to interfere with the encoding of feedback information. As a result, implicit memory processing deteriorates even further, thereby increasing feelings of doubt and uncertainty that give rise to checking compulsions. This mechanism can explain why the urge to check increases in situations of stress, for instance, when patients are responsible for the consequences of their own actions (Radomsky et al., 2001). Finally, we should note that it is not yet clear whether this mechanism is really specific for compulsive checking. The finding that the effect of feedback valence was absent in the entire OCD sample could indicate that compulsive washing is regulated by other motivational processes. For instance, it is possible that cleaning compulsions are driven by the desire to prevent the phobic fear from occurring, which means that it is a form of avoidance behaviour. Future studies on feedback processing in OCD should encompass a larger sample of both OCD washers and checkers in order to test the specificity of our findings.

We think that our findings add importantly to the research on self-regulation in OCD. The current study confirms that OCD is accompanied by a elementary deficit in processing feedback information, which could bring about both the difficulties with response evaluation *and* the subjective memory complaints. The results also suggest that the influence of emotions on self-regulatory processes may differ depending on the subtype of OCD. Furthermore, our data may help to

elucidate the neural network that underlies obsessive-compulsive behaviour. For instance, there is growing evidence that the ventral prefrontal cortex is crucially involved in visuomotor associative learning. Rhesus monkeys that underwent ablation of the orbital and ventral prefrontal cortex show profound impairments in visuomotor learning (Bussey et al., 2001). In addition, functional neuroimaging studies reveal that the orbitofrontal and inferior prefrontal cortex work intimately together with hippocampal and subcortical structures during the acquisition of new visuomotor associations (Passingham et al., 2000; Toni & Passingham, 1999; Toni et al., 2001). This could mean that the impaired associative learning of OCD patients reflects a decreased functionality of this ‘ventral network’. Interestingly, this idea is congruent with the reports of abnormal neural activation of the orbitofrontal circuit in OCD (Baxter et al., 1992; Perani et al., 1995; Swedo et al., 1989; Adler et al., 2001). However, we should add that additional studies are needed in order to spell out the exact nature of ventral system involvement in OCD. For instance, it has been suggested that only sensorimotor deficits are fundamental to OCD (Basso et al., 2001). This leaves open the possibility that the dysfunction of the ventral system is modulated by the type of information being processed. This is an issue that deserves further attention in future studies on feedback processing in OCD.

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